

CLAIMS

1. A phase contrast system for synthesizing an output electromagnetic field $u(x'', y'', z'')$, comprising

a first phase modifying element for phase modulation of an input electromagnetic
5 field by phasor values $e^{i\phi(x,y)}$,

first Fourier or Fresnel optics for Fourier or Fresnel transforming the phase modulated electromagnetic field positioned in the propagation path of the phase modulated field,

a spatial filter for filtering the Fourier or Fresnel transformed electromagnetic
10 radiation by

in a region of spatial frequencies comprising DC in the Fourier or Fresnel plane

phase shifting with a predetermined phase shift value θ the modulated electromagnetic radiation in relation to the remaining part of the
15 electromagnetic radiation, and

multiplying the amplitude of the modulated electromagnetic radiation with a constant B , and

in a region of remaining spatial frequencies in the Fourier or Fresnel plane,

20 multiplying the amplitude of the modulated electromagnetic radiation with a constant A ,

second Fourier or Fresnel optics for forming an electromagnetic field $o(x', y')$ by Fourier or Fresnel transforming the phase shifted Fourier or Fresnel transformed electromagnetic field, and

a second phase modifying element for phase modulating the electromagnetic field
25 $o(x', y')$ into the electromagnetic field $o(x', y')e^{i\psi(x', y')}$ propagating as the desired output electromagnetic field $u(x'', y'', z'')$.

2. A phase contrast system according to claim 1, wherein at least one of the first and second phase modifying elements is further adapted for phase modulation by first phasor values for a first polarization and second phasor values for a second
30 orthogonal polarization of the input electromagnetic field.

3. A phase contrast system according to claim 2, wherein the second phase modifying element is further adapted for phase modulation by first phasor values $e^{i\psi_1(x', y')}$ for a first polarization and second phasor values $e^{i\psi_2(x', y')}$ for a second orthogonal polarization of the input electromagnetic field.

5 4. A phase contrast system according to claim 2 or 3, further comprising an element for directing the phase modified orthogonal fields into separate paths of propagation, e.g. to be applied in a non-interfering counter-propagating geometry.

5. A phase contrast system according to any of the preceding claims, wherein

$$A = 1.$$

10 6. A phase contrast system according to any of the preceding claims, wherein

$$B = 1.$$

7. A phase contrast system according to any of the preceding claims, wherein

$$\theta = \pi.$$

15 8. A phase contrast system according to any of the preceding claims, wherein the phasor values $e^{i\phi(x, y)}$ of the first phase modifying element and the phase shift value θ substantially fulfil that

$$o(x', y') \cong A \left[\exp(i\tilde{\phi}(x', y')) + K \overline{|\alpha|} (BA^{-1} \exp(i\theta) - 1) \right]$$

wherein

20 A is an optional amplitude modulation of the spatial phase filter outside the zero-order diffraction region,

B is an optional amplitude modulation of the spatial phase filter in the zero-order diffraction region,

$\overline{|\alpha|} = \overline{|\alpha|} \exp(i\phi_\alpha)$ is the average of the phasors $e^{i\phi(x, y)}$ of the resolution elements of the phase modifying element, and

25 $\tilde{\phi} = \phi - \phi_\alpha$, and

$K = 1 - J_0(1.22\pi\eta)$, wherein

J_0 is the zero-order Bessel function and

η relates the radius R_1 of the zero-order filtering region to the radius R_2 of the main-lobe of the Airy function of the input aperture, $\eta = R_1 / R_2 = (0.61)^{-1} \Delta r \Delta f_r$.

9. A phase contrast system according to any of the preceding claims, wherein the phase shift value θ substantially fulfills the equation

$$5 \quad K|\bar{\alpha}| = \frac{1}{2|\sin \theta / 2|}$$

10. A phase contrast system according to any of the preceding claims, wherein at least one of the first and second phase modifying element comprises a complex spatial electromagnetic field modulator that is positioned in the path of the input electromagnetic field and comprises modulator resolution elements (x_m, y_m) , each

10 modulator resolution element (x_m, y_m) modulating the phase and the amplitude of the electromagnetic field incident upon it with a predetermined complex value

$$a_m(x_m, y_m)e^{i\phi(x_m, y_m)}.$$

11. A phase contrast system according to any of the preceding claims, further comprising a light source for emission of the input electromagnetic field, the light source comprising a laser array, such as a VCSEL array.

12. An optical micro-manipulation or multi-beam optical tweezer system according to any of the preceding claims.

13. A laser machining tool according to any of the preceding claims.

14. A method of synthesizing an output electromagnetic field $u(x'', y'', z'')$, comprising the steps of

phase modulating an input electromagnetic field by phasor values $e^{i\phi(x,y)}$,

Fourier or Fresnel transforming the phase modulated electromagnetic field,

filtering the Fourier or Fresnel transformed electromagnetic radiation by

in a region of spatial frequencies comprising DC in the Fourier or Fresnel plane

phase shifting with a predetermined phase shift value θ the modulated electromagnetic radiation in relation to the remaining part of the electromagnetic radiation, and

multiplying the amplitude of the modulated electromagnetic radiation with a constant B , and

in a region of remaining spatial frequencies in the Fourier or Fresnel plane,
multiplying the amplitude of the modulated electromagnetic radiation
with a constant A ,

5 forming an electromagnetic field $o(x', y')$ by Fourier or Fresnel transforming the phase
shifted Fourier or Fresnel transformed electromagnetic field, and

phase modulating the electromagnetic field $o(x', y')$ into the output electromagnetic
field $o(x', y')e^{i\psi(x', y')}$ propagating as the desired output electromagnetic field
 $u(x'', y'', z'')$.

15. A method according to claim 14, further comprising the steps of

10 dividing the electromagnetic field $o(x', y')$ into pixels in accordance with the disposition
of resolution elements (x, y) of a first phase modifying element having

a plurality of individual resolution elements (x, y) , each resolution element
 (x, y) modulating the phase of electromagnetic radiation incident upon it with
a predetermined phasor value $e^{i\phi(x, y)}$,

15 calculating the phasor values $e^{i\phi(x, y)}$ of the phase modifying element and the phase
shift value θ substantially in accordance with

$$o(x', y') \cong A \left[\exp(i\tilde{\phi}(x', y')) + K \overline{\alpha} \left(BA^{-1} \exp(i\theta) - 1 \right) \right]$$

wherein

20 A is an optional amplitude modulation of the spatial phase filter outside the zero-
order diffraction region,

B is an optional amplitude modulation of the spatial phase filter in the zero-order
diffraction region,

$\overline{\alpha} = \overline{|\alpha|} \exp(i\phi_{\alpha})$ is the average of the phasors $e^{i\phi(x, y)}$ of the resolution elements of the
phase modifying element, and

25 $\tilde{\phi} = \phi - \phi_{\alpha}$, and

$K = 1 - J_0(1.22\pi\eta)$, wherein

J_0 is the zero-order Bessel function, and

η relates the radius R_1 of the zero-order filtering region to the radius R_2 of the main-lobe of the Airy function of the input aperture, $\eta = R_1 / R_2 = (0.61)^{-1} \Delta r \Delta f_r$,

selecting, for each resolution element, one of two phasor values which represent a particular grey level, and

- 5 supplying the selected phasor values $e^{i\phi(x,y)}$ to the respective resolution elements (x, y) of the first phase modifying element, and

supplying selected phasor values $e^{i\psi(x',y')}$ to respective resolution elements (x', y') of a second phase modifying element having a plurality of individual resolution elements (x', y') , each resolution element (x', y') modulating the phase of electromagnetic

- 10 radiation incident upon it with the respective phasor value $e^{i\psi(x',y')}$ for generation of the output field $o(x', y')e^{i\psi(x', y')}$.